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Clouds and the atmospheric circulation response to warming

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We study the effect of clouds on the atmospheric circulation response to CO_2 quadrupling in an aquaplanet model with a slab-ocean lower boundary. The cloud effect is isolated by locking the clouds to either the control or $4xCO_2$ state in the shortwave (SW) or longwave (LW) radiation schemes. In our model, cloud-radiative changes explain more than half of the total poleward expansion of the Hadley cells, midlatitude jets, and storm tracks under CO_2 quadrupling, even though they cause only one-fourth of the total global-mean surface warming. The effect of clouds on circulation results mainly from the SW cloud-radiative changes, which strongly enhance the Equator-to-pole temperature gradient at all levels in the troposphere, favoring stronger and poleward-shifted midlatitude eddies. By contrast, quadrupling CO_2 while holding the clouds fixed causes strong polar amplification and weakened midlatitude baroclinicity at lower levels, yielding only a small poleward expansion of the circulation. Our results show that (a) the atmospheric circulation responds sensitively to cloud-driven changes in meridional and vertical temperature distribution, and (b) the spatial structure of cloud feedbacks likely plays a dominant role in the circulation response to greenhouse gas forcing. While the magnitude and spatial structure of the cloud feedback are expected to be highly model-dependent, an analysis of $4xCO_2$ simulations of CMIP5 models shows that the SW cloud feedback likely forces a poleward expansion of the tropospheric circulation in most climate models.